3.1 User Administration

3.1.1 APS Users

Selection Process

Users of the APS work either as members of Collaborative Access Teams (CATs) or as Independent Investigators.

Collaborative Access Teams. The CATs are selected by means of a comprehensive process developed in 1989. A prospective CAT submits a Letter of Intent (LOI), which is reviewed by the APS Program Evaluation Board (PEB), a six-member international scientific advisory body appointed by the Advanced Photon Source (see Table 3.1). If the LOI is approved, the prospective CAT is invited to submit a complete proposal. The proposal must include a description of the proposed scientific program, with emphasis on the need for the unique capabilities of the APS and the innovative nature of the research itself. The key personnel must be identified, and conceptual designs for both a bending-magnet and an insertion-device beamline must be presented. Additionally, the proposal must contain a description of the funding strategy and an outline of the management structure, as well as any special requirements for utilities or other facility or policy issues. The scientific sections of the proposals are reviewed by external appointed Scientific Review Panels, which send their reviews to the PEB. The PEB then invites the group to make a formal presentation. When a proposal is approved, the prospective CAT must submit a detailed conceptual design report, and a comprehensive management plan for APS approval, and it must document the intent of its funding agencies or sponsoring institutions to provide sufficient funding to complete the beamlines as originally proposed. When these requirements have been satisfied, the APS signs a Memorandum of Understanding (MOU) with the CAT and assigns a sector location on the APS experiment hall floor.

Independent Investigators. CATs select Independent Investigators by means of proposal processes developed and managed by the CATs. Each CAT is required to make a minimum of 25% of its beam time available to Independent Investigators, beginning one year from the time a particular experiment station in its sector is declared operational.

Current Status

Collaborative Access Teams. To date, the APS has received 37 LOIs, of which 25 have been approved by the PEB. Twenty-two proposals have been received, 15 of which were approved. Two additional proposals are expected for review by the PEB in May 1997. The 15 approved proposals account for 20 sectors and (owing to the recent merger of two CATs) represent 14 CATs. Memorandums of Understanding have been signed for 19 of these sectors; as soon as sufficient funding is received for the remaining sector, another MOU will be signed. Together, these CATs comprise 828 principal investigators and support staff from 168 home institutions.

Appendix 4 summarizes the APS reviews and approvals completed to date for each of the 14 CATs in allocating 20 sectors.

Independent Investigators. At present, none of the CATs have experiment stations that have been operational for a year. Independent Investigator access plans are now

Table 3.1 Past and Current APS PEB Members

Name	Affiliation	Term
Jens Als-Nielsen	Københavns Universitet	1989-1995
Howard Birnbaum Current Chair	University of Illinois, Materials Research Laboratory	1989-present
Roy Clarke APSUO Representative	University of Michigan	1993-1994
Stephen M. Durbin APSUO Representative	Purdue University	1991-1993
Alan I. Goldman APSUO Representative	Iowa State University	1994-1995
Wayne A. Hendrickson	Columbia University	1989-present
Paul Horn APSUO Representative	IBM	1989-1991
Michael L. Knotek Past Chair	Pacific Northwest Laboratory	1989-1995
Denis B. McWhan	Brookhaven National Laboratory	1995-present
Roger Pynn	LANSCE, Los Alamos National Laboratory	1989-present
Jochen R. Schneider	HASYLAB	1995-present
D. Mark Sutton APSUO Representative	McGill University	1995-1997

being developed by the majority of the CATs; however, these plans have yet to be approved by the APS.

3.1.2 User Administrative Functions

The APS User Office serves as the initial point of contact for prospective and incoming APS users and handles the following administrative and support functions: user communication, user access and orientation, conference/workshop planning and support, data management, and support of user advisory groups. Administrative functions handled by the XFD Division Office include user policy development, user agreement development, and user account management.

Communication

Primary means of communication with users include periodic mass mailings either to the entire user community or to APS CAT members; periodic e-mail messages to the user community or selected subsets (such as APS User Organization Steering Committee members, APS Research Directorate members, APS users on site, etc.); a periodic newsletter, *CAT Communicator*, which is sent to all APS CAT members and other selected individuals; and periodic World Wide Web postings. Other forms of communication include conference and workshop reports, the *APS User Guide* and *APS User Safety Guide*, and various technical memos and technical bulletins. Additionally, an electronic newsletter is now being developed, and a User Activity report, describing user science at the APS, will be produced for the first time in 1997.

To date, the APS has produced 17 issues of CAT Communicator, 6 Conference Proceedings, 15 Technical Memos or workshop reports, and 26 Technical Bulletins. (See Appendix 5 for a bibliography.)

User Access and Orientation

Argonne National Laboratory is a controlled access facility; consequently, APS users must have gate passes or APS user badges to enter the Argonne campus. The APS experiment hall itself is protected by a Cardkey™ access system (which should be activated in 1997). When a user registers with the APS and completes the core training requirements (described in the section on “User Safety and Training”), he or she will be issued an APS user badge (printed on Cardkey™ stock) that enables him or her to enter both the Argonne campus and the APS experiment hall through Cardkey™-controlled doors in the laboratory/office modules. User badges can also be used for access after normal business hours and on weekends to the APS central laboratory/office building, where the stockroom and library are located.

Conferences and Workshops

Conferences and workshops are planned regularly for the APS user community. User meetings are held approximately every 18 months. The First Users Meeting for the APS took place on November 13-14, 1986; the Eighth Users Meeting for the APS was held on April 15-17, 1997. Appendix 6 lists the conferences and workshops held since 1990.

Data Management

Information about APS users is stored in a relational data-management system developed by the APS User Office. This database is currently set up in a client-server configuration and is used by a number of APS staff members (including User Office and Division Office staff, Floor Coordinators, and procurement and accounting personnel) and Argonne staff (Conference Services and Human Resources) needing access to current APS user information. The Directory module is used throughout the APS as an electronic “Rolodex” for user contact information and is accessible on a “read-only” basis to anyone with database client software. Additional modules include CAT Information, User Accounts, User Agreements, Training, Registration, Beamline Design Reviews, and Meeting Registrations. Each module has separate read/write access privileges and is appropriately password protected. Modules under development include Program Evaluation Board, APS Users Organization, and Research Directorate modules, as well as an Independent Investigator proposal module. Plans are now being made to transfer the Directory module to the APS World Wide Web intranet for wider access.

Support of User Advisory Groups

Administrative support is provided to three main user-related advisory groups, as well as several other smaller groups.

The six-member Program Evaluation Board (which was formerly called the Proposal Evaluation Board) meets at least annually to review new Letters of Intent and new proposals and to conduct annual progress reviews of existing CATs.

The 18-member APS Research Directorate (RD) includes APS senior management and the Director of each APS CAT. The quarterly meetings of this Directorate are chaired by Associate Laboratory Director David Moncton and facilitated by a CAT Director (on a rotating basis). The primary purpose of the meetings is to serve as a forum for the discussion of CAT scientific management issues. Development of policy is an expected outcome. APS staff support to the RD includes the APS User Program Administrator, the APS User Technical Interface, and the XFD Assistant Director for Policy and Planning.

The APS User Organization Steering Committee meets quarterly and serves as a support, advisory, and advocacy group for the APS. The Vice-Chair of the User Organization serves as the Scientific Program Chair for User Meetings. The APS User Administrator serves as the primary APS liaison for this group.

User Policies and Procedures

The *APS User Policies and Procedures* is a comprehensive umbrella document being developed by XFD with input from other ANL organizations, the CAT Directors, the APSUO Steering Committee, and the APS Program Evaluation Board. Its purpose is to provide guidelines for all aspects of APS participation by both CATs and Independent Investigators and to clarify the roles of the APS staff and the various user advisory groups. The outline of the current version is shown in Appendix 7. As sections of the document are completed, they are distributed to the CAT Directors and posted on the Web.

One of the provisions of the MOUs that are signed by the APS and the CATs is a statement that the APS and the CAT will operate in accordance with the *APS User Policies and Procedures.*

User Agreements

To comply with the terms of the Prime Contract between DOE and The University of Chicago, Argonne National Laboratory (ANL) must sign formal User Agreements with the home institutions of all APS users. These agreements address a number of issues, including the general types of work users may do at the APS; payment for reimbursable expenses; intellectual property rights; liability and indemnification; ownership and disposition of property; requirements for approval of third-party contracts; and ANL’s right to stop a user’s work if safety rules are violated. In consultation with ANL's Legal Department, DOE, and the user community, XFD has developed the set of standard APS User Agreements that are now in use. XFD also manages the process of identifying the appropriate type of agreement for each institution and working with the institutional contacts to obtain signatures. As of this writing, APS User Agreements are in place with 58 institutions, including 28 universities and non-profit institutions, 17 industrial firms, 9 U.S. Government-funded labs, and 4 international institutions; another 14 institutions have received APS User Agreements for signature.

User Accounts

At the APS, as at all DOE User Facilities, users doing nonproprietary research (that is, research intended to lead to publication in the open literature) are not charged for machine time. However, DOE requires payment for machine time, on a full cost recovery basis, by users doing proprietary research; and all users must reimburse the facility for ancillary equipment, supplies, and services. The APS User Account system was developed and implemented by XFD, in collaboration with several other ANL organizations, to manage the reimbursement process. A given user institution may have any or all of the following types of APS User Accounts:

Construction accounts are used for certain categories of capital construction work performed by ANL employees or ANL subcontractors, such as utility installation along the beamlines and the buildout of office space inside the laboratory/office modules (LOMs).

Capital equipment accounts are used for beamline components (including radiation enclosures) purchased through or fabricated by XFD on behalf of a CAT for installation outside the shield wall.

Operating accounts are used for materials, supplies, and services. Examples include telephone service; items from the APS stockroom; Personnel Safety System installation; effort charges for employees hired by XFD and assigned to a CAT to perform scientific or technical work for the CAT; and space charges (i.e., building/utility/custodial charges associated with occupancy of LOMs).

Proprietary accounts are used for proprietary beam time.

As of this writing, 68 APS User Accounts are in place, serving 31 user institutions. XFD works directly with the users to establish these accounts, monitors the accounts with respect to dollar limits and expiration dates, and provides input to ANL's Accounting Department for the preparation of detailed invoices for all purchases.

We have been able to reduce APS users' beamline development costs considerably by including them under the umbrella of ANL's current "grandfathering" policy. By virtue of this policy, construction and capital equipment purchases by member institutions of existing CATs are exempt from ANL indirect charges until the end of FY 1997.

Advance payment is not required on any APS User Account that is funded with DOE money; also, as a result of intensive discussions between XFD staff and DOE-Chicago officials, advance payment is not required on operating accounts.

3.2 User Safety and Training

At the APS, safety is a line management responsibility that is shared by the CATs. The following are the basic elements of the approach used by the APS and the CATs to create and sustain a safe working environment for APS users:

- The CATs incorporate appropriate engineered safeguards into their APS facilities.
- Each CAT conducts its activities at the APS in accordance with a written safety plan developed by the CAT and approved by the APS.
- Users receive appropriate safety training for their activities at the APS.
- The APS, ANL, and the CATs themselves perform safety oversight of user activities.

The first of these elements is discussed in “Beamline Designs” (section 3.3.1). The others are discussed below.

3.2.1 CAT Safety Plans

Each CAT is expected to develop, and maintain as a “living document,” a safety plan that reflects the current makeup of the CAT’s safety program as the CAT organizes itself and moves through the installation and commissioning phases and into the operations phase. The plans are intended to supplement the *ANL Environment, Safety and Health (ESH) Manual*, which is incorporated by reference, and relevant safety manuals of the CAT member institutions. The preliminary safety plan (which is part of the written management plan that each prospective CAT submits as one of the prerequisites for obtaining a sector assignment) must describe the CAT’s commitment to safety, the safety responsibilities assigned to specific individuals, and the reporting relationships of these named individuals within the CAT organization. Before beginning hands-on work at the APS, each CAT must expand this write-up into a comprehensive plan that describes the CAT’s safety policies, organization, and management practices; identifies the specific hazards to which its users, and other individuals in or near its facilities, may be exposed; and describes how the CAT will control these hazards. The CAT safety plans must be approved by the Safety Plan Review Group, which is composed of XFD staff, before the CATs can begin the corresponding activities. Once a CAT’s safety plan is approved for a particular phase, a fundamental safety responsibility of the CAT is to conduct its on-site activities in accordance with that plan.

The Experimental Facilities Division has assisted the CATs in the development of their safety plans by providing a model plan that can be tailored to reflect each CAT’s activities and organizational structure. Some of the topics addressed in detail by the model plan are the distribution of safety functions within the CAT organization; chemical, electrical, and ionizing radiation hazards; power tools; personal protective equipment; construction areas; hazardous waste; sealed radioactive sources; hoisting and rigging; use of LOM shops; and work-area inspections. This model plan is a living document: the initial version, issued in October 1993, was followed by an updated version in August 1995 and supplements in May and June 1996 as needs for additional guidance were identified.

A key feature of each CAT's safety plan is the assignment of specific day-to-day safety responsibilities to an on-site CAT member, usually called the CAT Safety Coordinator. Typically, this individual advises the CAT Director on safety-related matters; works with on-site CAT management to ensure that the CAT's activities are consistent with its safety plan; conducts sector-specific and some task-specific training (see "User Safety Training" below); and serves as the CAT's primary contact with the APS on safety issues.

As of this writing, 14 CATs (covering 19 sectors) have APS-approved safety plans in place (see Appendix 4). Several of these CATs are currently expanding the scope of their plans in anticipation of their formal entry into the operations phase. In particular, they are filling in the details of their procedures for safety reviews of proposed experiments. For all CATs, this process will incorporate the use of a standard APS Experiment Safety Approval Form, which was adapted from the comparable form used at the National Synchrotron Light Source (NSLS). This form is completed in part by the experimenter, who describes the materials and equipment to be used, the known hazards, and the ways in which these hazards will be mitigated; and in part by the CAT Director or designee, who reviews the information, makes recommendations as needed, and ultimately signs off to indicate approval. The form must be posted at the beamline for the duration of the experiment. A Web-based system for completion and approval of the form is currently under testing.

3.2.2 User Safety Training

The responsibility for APS user safety training is shared by the APS and the CATs. This training falls into three broad categories:

"Core" training is required for all APS users and is administered by the APS User Office. As of March 10, 1997, 316 APS users have completed the core training program, which consists of the following elements:

APS User Orientation: This orientation, developed and updated as needed by XFD staff, is now being delivered to newly arrived APS users in a computer-based training (CBT) format; the topics covered include the role of the CAT safety plan, site alarms, emergency exits, use of 911, dosimeters, configuration control, management of hazardous chemicals, experiment safety review, and others. Additional safety information is provided by the *APS User Guide* and the pocket-sized *APS User Safety Guide*, both prepared by XFD staff; these booklets are part of the user registration package and are also posted on the Web. The CBT itself will be available via the Web in the future. All incoming users sign a statement confirming that they have read and understood both the *APS User Guide* and the User Orientation and will follow the guidelines given there.

General Employee Radiation Training (GERT): The GERT training is a general APS requirement consistent with DOE policy. APS users who do not have a current GERT card from another DOE facility must pass a computer-based GERT exam. They may prepare for the exam by taking a CBT course at the APS or via the Web, or by reading a hard-copy study guide, which is part of the user registration package.

Generic Personnel Safety System (PSS) training: APS users view a videotaped introduction to the operation of the PSS.

Sector-specific training is also required for all APS users; it is administered by the

CATs as a face-to-face orientation/demonstration. To facilitate this training, XFD has provided a model checklist of topics to be covered; each CAT may modify the list as necessary. The training focuses on communicating specific information needed to implement the CAT's safety plan; examples include locations of utility shutoffs, chemical storage locations and practices, procedures for obtaining and transporting liquid nitrogen, and beamline-specific operation of the PSS. The CAT signs off on the checklist and sends a copy to the APS User Office to verify that each new user who will be working under its auspices has completed this training. As of March 10, 1997, the User Office has received signed-off "sector orientation records" for 97 APS users.

Only APS users who have completed both core and sector-specific training are given Cardkey access to the APS.

Task-specific training is the third element of APS user training. The CATs identify task-specific training needs for their personnel and users in accordance with their CAT safety plans. Qualified CAT staff members may perform some of this training themselves; two examples are training users to operate the hoists in the experiment stations and orienting experienced machine tool users to the CAT's LOM machine shop. Many other task-specific training needs are met, in whole or in part, through courses offered by ANL's ESH Division; the XFD ES&H Coordinator's office handles user enrollments in these courses. XFD supports the course selection process both by one-on-one consultation with users and by maintaining an XFD-developed computer program that matches available courses and certifications to planned activities. XFD has also worked closely with the ESH Division's Training Section (ESH-TR) to tailor courses and course requirements to APS users' needs.

To date, 24 different ESH-TR courses have counted APS users among their graduates. Some examples follow, along with the numbers of APS users who have completed each course to date:

ESH-119, Pressure Safety Orientation (18)

ESH-145, Cryogenic Safety (16)

ESH-195, Personal Protective Equipment (17)

ESH-574, Chemical Waste Generator (18)

3.2.3 User Safety Oversight

The responsibility for user safety oversight, like the responsibility for safety training, is shared by the APS and the CATs. The APS Floor Coordinators perform informal day-to-day safety oversight of user activities; XFD also has the lead role in formal user safety oversight, with two programs currently in place:

Reviews of CAT safety plans: As mentioned earlier, an XFD committee reviews the CAT safety plans to ensure that they are adequate for the upcoming phase of sector development and operation. The outcome of a typical review is an acceptance letter with detailed recommendations for improving the plan as the CAT implements the activities described therein.

Inspections of CAT-occupied areas: Periodic walkthroughs are conducted by the XFD ES&H Coordinator, with invited participation by safety specialists from the Fire Protection, Industrial Hygiene, Health Physics, and

Safety Engineering Sections of the ANL ESH Division. XFD then provides the CATs with written recommendations for addressing any concerns that are identified.

In addition, a procedure for XFD oversight of the CAT-managed experiment safety review process is currently under development.

To take advantage of the CATs' experience in managing their own safety programs at the APS, XFD has initiated the formation of three Safety Oversight Committees within which the CATs will conduct reciprocal assessments of each other's safety programs. Each CAT has been asked to name a representative to one of these committees, also known as "mutual safety assessment groups"; each CAT will then be reviewed by the others in its group on a rotating basis. Alternatively, a CAT may organize its own Safety Oversight Committee consisting of safety experts from its member institutions or ANL; the selection of members for such independent committees is subject to APS approval.

The CAT Safety Oversight Committees may adopt a set of model assessment criteria that have been provided by XFD, or they may develop their own criteria and obtain XFD approval. Each CAT will be reviewed at least annually by its fellow committee members and will receive a written report (which will be copied to XFD) identifying action items and a schedule for completing these actions. The committees will also be encouraged to make recommendations to the APS for enhanced safety support.

To date, 13 CATs (accounting for 16 sectors) have signed on to participate in mutual safety assessment groups; XFD is currently working with one of the three groups to "pilot" the assessment process.

3.3 User Technical Support

3.3.1 Beamline Designs

Overview

The CATs are responsible for the design of their beamlines and their associated experimental facilities. The APS supports these efforts through the development of standardized designs of many beamline components, working through a design review process to ensure that the plans meet applicable standards, and providing incidental design engineering for conventional construction. Standard designs are available to the synchrotron community through the APS Design Exchange (DX), which is described below. The formal review process extends from the conceptual design through preliminary and final beamline designs. The review process is described in detail in the following sections.

In the first step in a beamline design review, as part of the proposal process, the CAT develops a Conceptual Design for the planned beamline. The Conceptual Design is reviewed by an Instrumentation Feasibility Study Panel of the Program Evaluation Board. An approved Conceptual Design is one of the prerequisites to assigning a specific APS sector to a CAT for the construction and operation of beamlines. Once the proposal has been approved and a sector has been assigned to a CAT, the CAT will proceed to develop detailed beamline designs.

The APS/XFD has created a Beamline Review Committee (BRC) to review the design and operation of each beamline. It is composed of APS scientists and engineers who are familiar with beamline technical requirements and is chaired by the group leader of the User Technical Interface Group. Advisors from other areas of ANL are added as issues are identified for which adequate expertise does not exist within the committee.

Beamlines are reviewed to ensure that their designs (1) are consistent with the proposed scientific program and (2) satisfy all APS, ANL, and DOE requirements for safe operation. The documents developed for the review are kept on file in the APS User Office for future reference. In addition, at each review stage, drawings of the beamline and its components are filed in the DX, through which current electronic or paper copies of beamline layouts can be accessed as needed. The review process is intended to identify issues that must be resolved before beamline installation or commissioning begins.

The BRC reviews the beamline at several stages: (1) Preliminary Design Review; (2) Final Design Review; and (3) whenever significant modifications are to be made that may affect the safety aspects of the beamline, such as shielding, additional beamline sections, etc. Appendix 4 summarizes the status of these reviews.

Preliminary Design Review

The preliminary design of the beamline represents completion of approximately 30% of the design effort for each of the beamline components. This level of design permits the CAT to develop cost estimates for the construction of the beamline, as well as a realistic timeline for completion of the construction tasks. Following guidelines provided by the APS, the CAT prepares a Preliminary Beamline Design Report (PDR) for APS review. The PDR must include the following elements:

Beamline layout

- Layout of the beamline within the sector, showing components and support equipment
- Life Safety Code compliant egress aisles
- Some indication of the plans for survey and alignment of the beamline components

Component designs

- Appropriate specification of components that are not APS-developed standard components
- Assurance of compliance with APS policies, such as the APS vacuum policy
- Description of the optical and shielding apertures with ray-tracing analysis and the existence of a reasonable safety margin for white-beam components

Management issues

- Demonstration of a Work Breakdown Structure (WBS) with preliminary costs and schedules

Special operating requirements

- Identification of any special requirements and an evaluation of compatibility with the installed conventional facilities

Preliminary safety analysis

- Analysis of the shielding design for compliance with APS shielding standards
- Definition of the proposed modes of beamline operation, together with the expected requirements of the PSS
- Description of the beamline EPS and an assurance of compliance with the APS policy on white-beam beamline components
- An ozone mitigation plan with a preliminary analysis of ozone production within the beamline
- Identification of and preliminary mitigation plans for program-specific hazards, (hazardous gases, radioactive materials, etc.)

Final Design Review

The next phase of the APS beamline review process focuses on the Final Beamline Design Report (FDR), which is submitted when approximately 90% of the total design effort has been completed. APS approval of the CAT's designs described in the FDR is required prior to installation of beamline components in the APS experiment hall. Items that have a long lead time for design or procurement may be reviewed separately from the remainder of the beamline, but enough information must be provided so that reviewers can understand the context in which these components are to be used. Those components that are part of the APS standard component list are not reviewed for their individual performance; however, the components are reviewed in the general scheme of the total beamline performance.

The review of the PDR focused on the layout of the beamline as a whole and at a level that would permit the beamline components to be designed independently of each other. The FDR review focuses on aspects of safety, scheduling, required APS support, and updating the information provided in the PDR. The topics to be addressed in the FDR are as follows:

Layout

- Identification of changes from PDR layout
- Survey plan, including expected APS survey and alignment support
- Update of the ray traces provided in the PDR

Component designs

- Component final designs
- Assurance of compliance with the APS vacuum policy

Schedule, cost, & WBS

- Installation schedule with indications of the expected APS craft support
- Survey and alignment schedule

- Update of the WBS-based schedule given in the PDR

Safety

- Final PSS requirements

- EPS logic and interface requirements

- Description of final shielding design

- Identification of chemical, electrical, fire, and other hazards that impact beamline design, and means to be used for mitigation.

- Identification of program-specific hazards (high powered lasers, biohazards, etc.)

Special operating requirements

- Identification of special conventional-facilities requirements

3.3.2 Beamline Design Exchange

Overview

At the APS, all the ID front ends are of one standard type and all the BM front ends are of a second standard type. Likewise, all the common components of the beamlines themselves have been standardized (Kuzay, 1992; Shu et al., 1995), hence the name “APS standard components.” The standard front-end and beamline component designs, technical specifications, and statements of work for procurement are all housed in a sophisticated electronic depository called the APS Design Exchange (DX), a part of the Beamline Engineering Group. The choice of standard components and their designs (which were prepared by XFD staff) have been reviewed by an independent committee of experts external to XFD.

The purpose of the DX is to distribute APS beamline component drawings and related technical information to the APS user community. This information is available on the Internet (or World Wide Web) to individuals with current passwords. However, comprehensive information has been provided with open access to explain to interested parties the operational features and access to the DX. Special care has been taken to make the DX Web site user friendly. General access to the DX on the Web is at the URL (uniform resource locator): <http://dxchange.aps1.anl.gov/>. Access to DX drawing libraries is password controlled to assure quality control, security, and intellectual property rights.

The majority of APS users (CATs) have chosen to use APS standard components, or somewhat modified forms of them to suit their specific needs, in their beamline designs. Hence the DX has become a major user support facility.

In addition to being an electronic copy depository, the DX has also been the source for creating both the logical drawing numbering system (universally adopted and used at the Advanced Photon Source Project) and the standard component naming conventions for cataloging and indexing these diverse components in a systematic way. It contains sophisticated search engines and electronic data storage and backup systems.

Table 3.2 lists the holdings contained in the DX.

Table 3.2 DX Holdings in the Electronic Depository[1]

Total number of passwords issued to the DX:	188
Total number of drawings available in the DX General Library in *.dwg format:	2455
Total number of drawings available in the DX General Library in *.dxf format:	2455
Total number of drawings available in the DX General Library in *.gif format:	2455
Total number of zipped libraries available in the DX General Library:	161
Total number of component catalog pages available in the DX General Library:	34
Total number of drawings contributed by CATs, available in the DX shared library:[2] (The contributing CATs are CARS and IMCA.)	95
Total number of new and revised drawings uploaded to the DX since Aug. 18, 1995:	600

1 This information can be found on the Web at URL: <http://dxchange.aps1.anl.gov/Login/nph-scanupdate.cgi> (authorized password required).

2 The following CATs have submitted their review drawings to the DX: BESSRC, CARS, DND, IMCA, IMM, PNC, SBC, SRI, UNI

Usage Statistics

To date, more than 9,000 logins to the DX have been recorded, and more than 190,000 files have been downloaded.

Hardware and Software

Both the hardware and software for the DX have been developed in a systematic way since 1991. In 1993, the APS DX was initiated as a Web server to allow sharing of APS-designed standard components with CAT members around the world. The DX was the first Web server at the APS Project.

In late 1994, the role of the DX was broadened to include acting as a local server for XFD engineering and design personnel. In addition, special accounts are set up for the CATs to allow direct uploading to their individual shared or private libraries.

In January 1996, an Exabyte EXB-10h Autochanger was purchased. The EXB-10h is a 14 GB per tape autochanger with 10 tape slots. A Legato Networker was the choice for a backup utility. Currently, we have the capability of handling a total of 45 clients on different platforms.

Current Activities

In recent months, the DX activities have shifted to accommodate new requirements of the users. Less time is spent uploading new designs to the libraries, and more hours are spent assisting CATs planning to install APS-designed standard beamline components. Many questions directed to the DX office address engineering issues, manufacturing techniques, and the interfacing of drive systems, encoders, and safety switches, as well as document and source information. We believe that our support to the CATs substantially reduces the learning curves for individuals who are responsible for installing beamline components at the APS.

Another beneficial spin-off from the DX is the relatively effortless development of an electronic data storage system. This new system permits us to centralize our entire file system of computer-created drawings. When completed, it will also function as our official archive for electronic files with practical quality assurance and search tools in place. This work is done on a limited part-time basis with available in-house resources.

3.3.3 X-ray Optics Metrology and Fabrication

The APS Metrology Laboratory

Introduction

Over 50 major mirrors are expected to be installed and used on the APS beamlines. These will be used for harmonic rejection, focusing, power filtering, or beamline branching. Before being shipped, mirrors are often evaluated by the vendor, in terms of figure and finish (i.e., slope error and roughness), as part of their quality-assurance process. However, there is a need for an independent evaluation of the optical surfaces of mirrors as part of the acceptance criteria before they are installed and commissioned on the beamline; the metrology laboratory at the APS has been built to fulfill this task. In the following sections, a basic description of the metrology instruments is provided together with a discussion of the surface quality of mirrors measured to date (also see Bresloff & Mills, 1996, and Assoufid & Mills, 1997). Finally, some future developments are outlined.

The Metrology Laboratory Environment

The laboratory is located in a class 10,000 cleanroom in the APS experiment hall. Mirror handling requires special cleanroom garment and shoe covers, and access to cleanrooms is restricted when measurements are performed.

To ensure repeatability and accuracy of the instruments, the room temperature stability is controlled to better than +/- 0.5 °C and is regularly monitored. All instruments are mounted on air tables to minimize the effect of vibrations, and they have the capability of handling large and heavy optics up 2 m in length and 90 kg in weight.

The Metrology Laboratory Instruments

The laboratory has three different instruments to evaluate optical surfaces over a range of spatial periods from a few microns up to 2 meters. These instruments are:

Long Trace Profiler (LTP). The LTP is an instrument designed to measure slope error and curvature of optical surfaces up to 2 m long. It has a sensitivity of 0.1 µrad in slope and 0.5 nm in height and a reproducibility of better than 0.5 µrad rms. Because of its speed, it offers a rapid and accurate means of evaluating the performance of a mirror bending mechanism. A recent adaptation of the LTP allows it to measure a surface profile of a mirror in either the horizontal or vertical direction. Measurement in the horizontal direction is often desirable because it eliminates gravitationally induced figure distortion. Figure 3.1 shows a photograph of the LTP system with the high heat load mirror for the 2-ID beamline being evaluated in the horizontal position.

TOPO Surface Profiler. The TOPO is a microscope-based instrument that uses visible-light (630.3 nm) interferometry to measure surface roughness on the order of an angstrom. The optical head of the TOPO profiler can use either a 3D or 2D detector and is currently equipped with three objectives: 1.5x, 5x, and 40x. The 3D detector is used when a profile of a surface area (of a few mm^2 depending on the objective) is needed with a minimum resolvable height of 3 Å. The 2D detector obtains a line scan with a resolution of 1 Å along a line up to a few millimeters long, depending on the objective (e.g., 2.05 mm for a 5x objective).

WYKO 6000 Figure Interferometer. The WYKO-6000 measures the flatness of optical surfaces interferometrically by a technique similar to that of the TOPO. It is used for characterizing optical surfaces up to 6" in diameter (or large optics at grazing incidence angles).

All these instruments are currently operational. Various modifications of the basic systems are being developed for ease of operation and to improve handling of large optics.

To enhance the capability of the metrology laboratory, a fourth instrument, an atomic force microscope (AFM), is scheduled to be installed and commissioned beginning in April 1997. The AFM will be used, for example, to measure surface roughness, evaluate diffraction gratings, and measure thin-film step height. This instrument will be a valuable tool for better understanding surface topography on the atomic scale and relating it to light scattering. In addition, the results can be used to improve methods for making optical surfaces.

Surface Quality of Some Mirrors Measured to Date

In the past two years, more than ten major beamline mirrors, some up to 1.5 m long, as well as a variety of smaller optics, have been evaluated in the APS metrology laboratory. Most of these mirrors will be used on the APS beamlines and have been designed and procured by APS users, including members of SBC-CAT, SRI-CAT (Yun et al., 1996; Khounsary & Yun, 1996; Lai et al., 1996; Randall et al., 1995; and McNulty et al., 1996), and DND-CAT. Two mirrors have been designed and are destined for other facilities in the USA, namely CHESS at Cornell University, and the Center for Advanced Microstructure and Devices (CAMD) at Louisiana State University. Surface microroughnesses ranging from 1 to 10 Å and slope errors ranging from 1 to 4 microradians have been characterized and were found to be consistent with vendors' measurements. To avoid bias, data from the vendors were obtained only after all metrology measurements were completed and analyzed. Appendix 8 summarizes the results for mirrors to be used on the APS beamlines. To date, most of the mirror substrates have been made of either silicon or Zerodur; the others have been made of Glidcop and float glass. Most

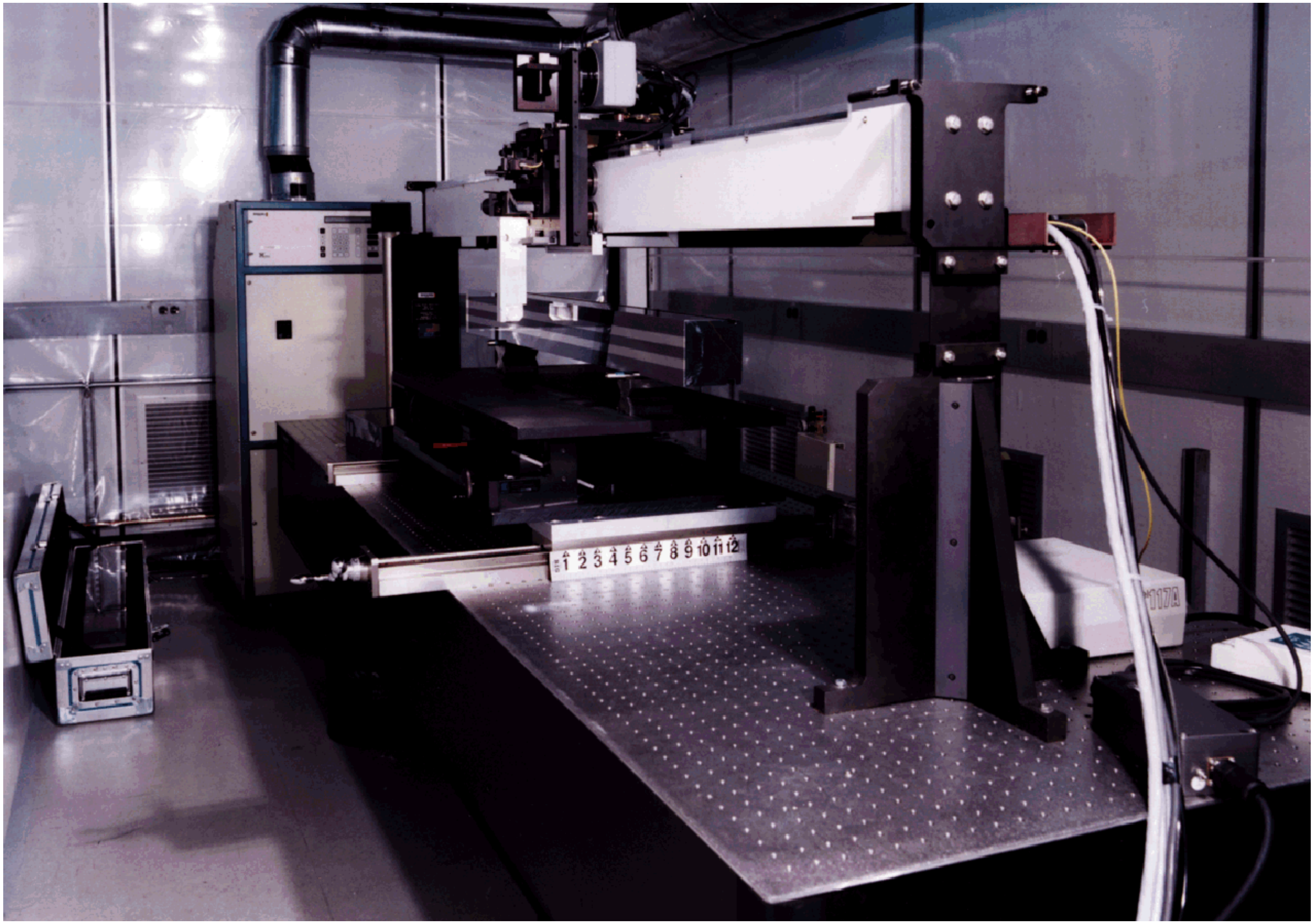
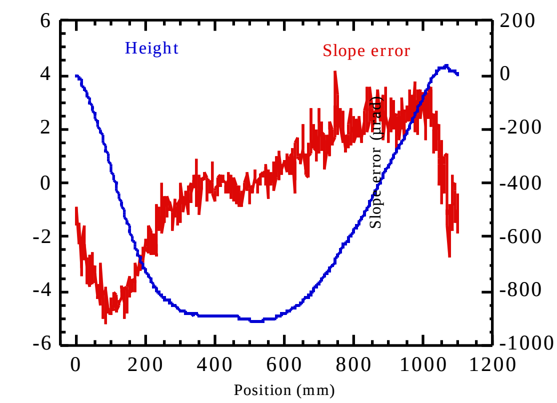


Fig. 3.1 Photograph of the LTP system with the 2-ID high heat load mirror set up to be measured in the horizontal position.

surfaces have at least one reflective coating; platinum and rhodium are typical reflecting materials. Figures 3.2a and 3.2b show a typical output from the LTP. The results are for the 2-ID high heat load mirror (see Appendix 8), which is the first long mirror to be evaluated at the metrology laboratory. This mirror has been installed on Sector 2 and has performed well. Figure 3.2a shows the slope error profile (red curve) along with the corresponding height profile (blue curve) obtained by averaging five scans on the mirror center line. Figure 3.2b gives the power spectral density of the derived average height profile. The power spectral density is useful for computing the rms statistics over a selected spatial frequency bandwidth. This allows one, for example, to separate “mid-frequency ripple” from overall surface figure.

(a)



(b)

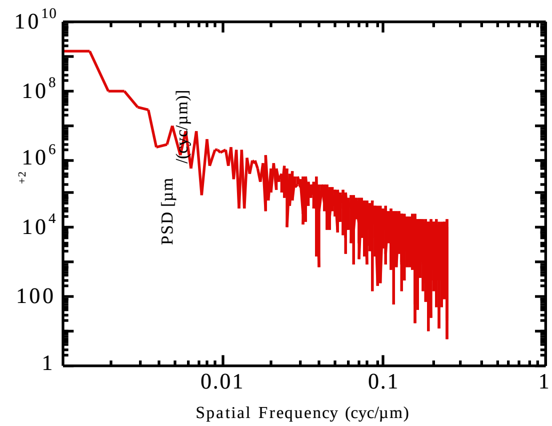


Fig. 3.2 Example of the LTP output. Shown are results for the high heat load M1P mirror for beamline 2-ID: (a) slope error and the corresponding height profile obtained by averaging 5 scans along the mirror center line, (b) power spectral density of the derived average height profile. The mirror is 1.2 m long and has a slope error of 2.2 μrad rms. The corresponding rms height is 210 nm, over a 1100 mm aperture.

Coating Facilities

To help develop reflective optical elements as well as experimental samples for all the APS users, we have established three coating facilities in recent years: (a) a 1.5 m sputter deposition facility, (b) a small sputter deposition facility, and (c) an evaporation facility. These facilities are briefly described below.

Facility Descriptions

1.5 m Sputter Deposition Facility. This facility, shown in Figure 3.3, is located in the deposition lab, on the experiment hall floor next to Sector 1. The deposition lab is in a class 10,000 clean room with a gowning room entrance. The 1.5 m sputter deposition facility, also referred to as the large deposition system, consists of four large vacuum chambers, each 16” in diameter and 66” long. The first chamber next to the clean hood is a load lock chamber isolated from the other three chambers by a computer-controlled gate valve. Three CTI model CT-8 cryopumps and an Alcatel ADP 81 dry pump provide a base pressure of < 5 × 10^{-8} Torr for the system.

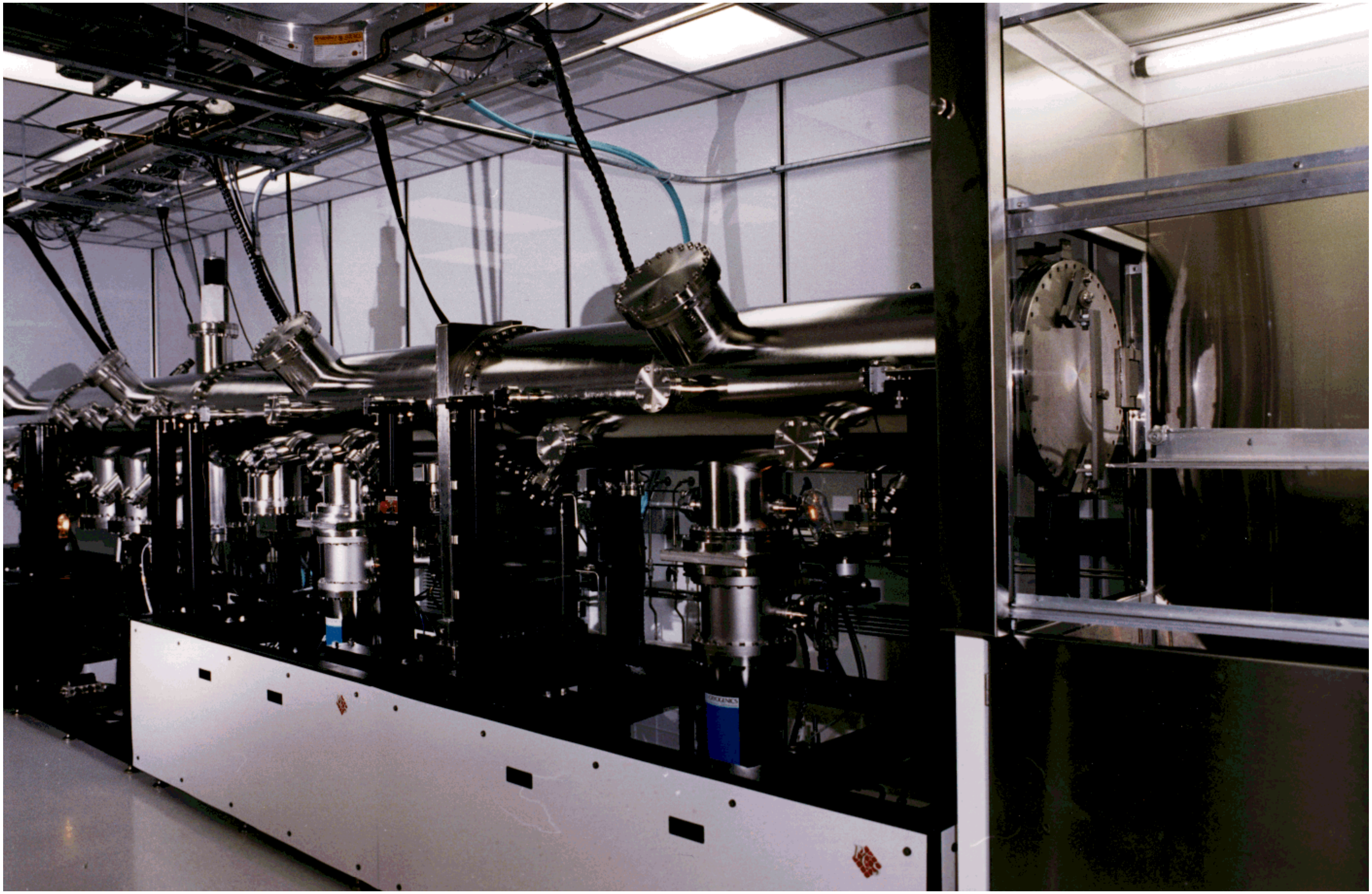


Fig. 3.3 The 1.5 m sputter deposition facility.

Mirror substrates as large as 150 cm long, 20 cm wide, and 14 cm high can be loaded into a substrate carrier inside the vacuum system using guard rails. The substrate can be outgassed in the load lock chamber using a UV lamp. The substrate-carrier transport assembly is driven by a stepper-motor. The full length of a 1.5 m substrate can be coated using the transport assembly.

The third vacuum chamber is the deposition chamber, where four ports on the bottom along the chamber axis are designed to house the sputter cathodes. Currently two 3” diameter magnetron sputtering guns compatible with both DC and RF operations are deployed. The coating is deposited in an upward direction with the substrate facing down. Argon pressure during the deposition is regulated by a MKS model 250 process controller, with the cryopump throttled. A coating uniformity of better than ±5% over a 4” width has been achieved using a rate-controlling aperture over the target source and the linear motion of the substrate. Similar uniformity over an 8” width can be obtained by using two specially arranged guns.

Small Sputter Deposition System. This system has two 3” diameter DC magnetron sputter guns, located at the bottom of a 9.5” OD, 4’ long vacuum chamber. The vacuum chamber is pumped by a turbo-molecular pump and has a base pressure in the 10^{-7} Torr range. The system is designed to handle small substrates up to 4” long and less than 0.5” thick. The substrate-carrier transport assembly has a travel distance of ~3 feet. A uniformity of better than ±5% can be obtained by using shaped apertures over the targets and the linear motion of the substrate. The argon pressure during deposition is regulated by using a throttled valve on the pumping station and a MKS process controller. The system is computer controlled and capable of making both single and multilayer coatings.

Evaporation Facility. This facility was created from an existing surface analysis facility, which is equipped with a Fisons Instruments CLAM 2 electron energy analyzer, an electron gun, a surface-cleaning sputter gun, and a residual gas analyzer. It is an ultrahigh vacuum system with a base pressure of $\sim 5 \times 10^{-11}$ Torr. Small samples (up to 0.875” × 0.625”) can be loaded to a heating/cooling stage on a XYZ manipulator through a load lock system. Ports at a lower level (compared to the analyzer level) on the vacuum chamber are available and can be used for thin-film deposition.

Miniature e-beam evaporators and precision-temperature-controlled thermal evaporators were invented and made in-house for physical vapor deposition of thin/ultrathin films. At present, two evaporators are placed ~20° apart so that alloy thin films can be made via co-deposition. A quartz-crystal thickness monitor is installed to monitor the evaporation rate before deposition. A third evaporator is installed in another vacuum port so that a protective coating can be deposited on the sample. The composition and uniformity of alloy films can be analyzed *in situ* using Auger electron spectroscopy. This system is suitable for MBE-type sample preparation.

Current Activities

With these three facilities, we are capable of fabricating virtually any kind of physically deposited thin film/multilayer for the APS users. To date, we have made over 100 depositions for the users and have accumulated experience on various thin film/multilayer systems. There are five major applications that require our deposition system: (1) hard x-ray mirrors, (2) soft x-ray mirrors, (3) multilayer focusing mirrors, (4) coatings for x-ray lithography testing, and (5) other thin-film/ multilayer samples for scientific research.

Common substrates for x-ray mirrors include float glass, fused silica, silicon, Glidcop, etc. Coating materials are typically Au, Pt, Rh, W, Ni, Cr, Ti, etc. Float glass used as a substrate has the advantage of a very low cost and reasonably good flatness. When it is coated with a *glue* layer of Cr or Ti, the subsequent coating of metals, such as Au and Pt, has good adhesion. Cr (Ti) can form covalent bonds to the glass by breaking the O-Si bond, and metallic bonds to other metals. Satisfactory results have been obtained for a batch of Au/Cr-coated float glass mirrors that we made for CARS-CAT. These mirrors are used for microfocusing of hard x-rays. Using these mirrors, CARS-CAT has successfully focused a 60 kV x-ray beam into a $6 \times 8\ \mu m^2$ spot. The gold coating remains intact after being subjected to hard x-rays, with no coloring, no clustering, and no cracking. A 56" long Au/Ti-coated mirror on float glass has also been fabricated for CAMD. It will be used as a soft x-ray mirror. Successful cleaning methods have been demonstrated, which ensure a flat coating comparable to the substrate flatness.

Multilayer mirrors mostly utilize a high Z/low Z configuration. Common combinations are W/Si, W/C, and W/BC_4. These multilayers require a good thickness control and a stable deposition rate. For example, Prof. S. Durbin from Purdue has requested a W/C multilayer of 100 pairs of W and C with individual W and C layer thicknesses of 1.5 nm or less. A test multilayer of this kind has been fabricated recently on a silicon substrate. Other multilayers include Ni/C, Ni/Al, Pt/Al, W/Al, etc. Most of them are still in an experimental stage. We expect that the need for multilayer mirrors will grow substantially as more and more CATs start beamline commissioning.

Metal coatings are also used in x-ray lithography experiments. In x-ray lithography, one needs a conducting layer on the silicon wafer to put on the photoresist layer. This conducting layer is later used as a base for electroplating, after which a pattern is formed through x-ray lithography. To date the most common conducting layer we have used is Au. We have grown Au/Ti, Au/Cr, Ti, etc., on silicon and Be wafers. The Si wafer substrates worked very well. Currently we are experimenting on the metal/Be system.

Other coating applications include protective coatings, laser-mirror coatings, and other coatings for some special experiments. For example, by making special masks, we could make thin film/multilayers with specified shape and dimensions, which are very useful for some experimental studies.

On the evaporation front, we are growing $Fe^{57}Sn^{119}$ alloy films. These isotopes are very expensive, and it is not practical to use sputter deposition. Test samples have been made on glass and Cr/glass substrates. They are then coated *in situ* with Si as a protective layer. Final samples will be made on Cr-coated fused silica substrates.

In summary, we have built basic coating facilities and started serving the APS community. We are continuing to improve our capabilities to meet the ever-increasing demand from our users.

Fabrication Laboratory

The fabrication laboratory manufactures crystal elements needed for x-ray beamlines at the APS. The lab is supplied with the following equipment:

Crystal Cutter (Meyer-Burger TS121). This CNC-controlled saw accommodates diamond blades up to 16” diameter and can move a crystal along three mutually orthogonal directions with the travels up to 500 mm (X), 320 mm (Y), and 160 mm (Z). Additionally, the object (crystal) can be mounted on a rotary table and/or on a large sine bar.

STRASBOUGH 6DF-1. This lapper/ polisher is set up for coarse lapping of optical components (up to 12” dia). Slurries containing lapping compounds with grains of 50 and then 9 micrometers are used.

HYPREZ (ENGIS Corp. IL). This lapper/ polisher is for fine lapping of optical components (up to 12” dia.) with slurries containing 6 micrometer lapping grains.

STRASBOUGH 6DF-1. This lapper/ polisher is set up for final polishing of optical components (up to 12” dia.) with slurries containing 3 to 0.25 micrometer polishing grains.

Two ovens are available. The first oven is used for attaching (waxing or glueing) crystals to substrates/holders used during fabrication operations. The second one can be employed for annealing processes.

Two chemical hoods (lengths 8’ and 6’) are available for etching. (They are equipped with a special drain system.) In practice, one hood is predominantly utilized for etching, the other for work with solvents.

A crystal direct bonding setup consisting of a small laminar hood, wafer spinner, and fresh deionized water production line is used for experiments on silicon-to-silicon direct bonding. Wafers of up to 4” diameter can be placed on the spinner.

During the last year, the fabrication laboratory has manufactured 47 optical elements for use by various CATs in monochromators, analyzers, and interferometers.

X-Ray Laboratory

The objective of the x-ray laboratory is to support operation of the fabrication laboratory and activities of other XFD groups that make use of conventional x-ray generators. The lab is supplied with the following equipment:

Rigaku X-ray Generator. This Rigaku x-ray generator produces x-rays in conventional tubes (typical targets, Cu and Mo; maximum power about 2 kW). Two horizontal beamlines (point focus) are available. The beam emerging from the right port is collimated and employed for orientation of ingots or precut crystal pieces. A single-axis, manually operated diffractometer (Huber 424 goniometer) is used for crystal and detector rotations about the common vertical axis. Samples tested with this crystal orienter are usually fixed to holders that can be mounted on the crystal cutter table. The orienter is used frequently.

The beam from the left port is used for work with a double-axis diffractometer. The diffractometer is a commercial instrument made by Blake Industries, Inc. Only precise made by Blake Instruments, Inc. Only precise rotation of the sample table is automated and controlled by computer via EPICS. After reflection from a monochromator, the x-ray beam typically has a 2 × 2 mm footprint and is predominantly used for taking rocking curves. In the past, the instrument was very often employed for local testing of samples. It was also used for testing interferometers and area detectors.

Spellman X-ray Generator. X-rays are produced in conventional tubes (typical targets, Cu and Mo; maximum power about 2 kW). Two horizontal beamlines (point focus) are available. The beam from the left port can be utilized in an 8’ × 9’ × 8’ enclosure attached to the left side of the generator tower shielding. The enclosure can be entered through two sliding doors and can accommodate large size equipment. In the past, this beam was predominantly used for testing different kinds of prototype high heat load monochromator setups that were later installed at the APS ring.

The beam from the right port is shared by two types of experiments. A Laue camera may be installed just next to the beam port, and a pattern of backscattered reflections from a crystal can be examined. When the Laue camera is removed, the primary beam can be transported through a long vacuum tube to a separate enclosure. This additional chamber is primarily used for double-crystal reflection experiments requiring highly collimated primary beams.

Rigaku X-ray Generator. This second Rigaku x-ray generator is a rotating-anode-type generator with a maximum power of 18 kW. Targets made of copper or molybdenum can be mounted. Two horizontal beamlines (point focus) are available. The beam from the right port is employed for work with a triple-axis diffractometer. The diffractometer is a mixture of purchased commercial units made by Blake Industries, Inc. (monochromator enclosure) and Huber (Two Circle Goniometer 422 and 511.1 Eulerian Cradle), and custom elements (coupling between the monochromator unit and the Huber goniometer, air pads lifting the goniometer, and the analyzer subassembly). This diffractometer was recently upgraded and is now routinely used for reflectivity measurements (so far, for checking the quality of samples later employed for experiments at the APS).

The primary beam emerging from the left port is transported in a long vacuum tube to another enclosure that surrounds a double-axis x-ray diffractometer called the Topo Test Unit (TTU). This station was designed and built in-house for topographic testing of x-ray optics elements. The distance between the source and the diffractometer axis 1 is about 2 m. The primary beam-transport tube ends about 180 mm upstream from axis 1 (there is space available for long monochromators) and serves as a base for an entry slit system and an additional lead enclosure surrounding the first crystal.

The diffractometer is mounted on a special base composed of two separate plates that can be moved independently along two common, exactly parallel, precise rails. The so-called right base plate supports the first crystal table, while the rest of the diffractometer stays on the left base plate. The objective of the design was to build a machine capable of testing (in some steps) samples of front-face size up to 300 mm × 90 mm. With highly asymmetric cut monochromator crystals, a typical footprint of the monochromatic beam is 80 mm × 90 mm. The take-off (two theta) angle for the monochromatic beam can be manually adjusted in the range from 0 to 120 degrees.

The distance between axes 1 and 2 can be fixed in the range 560 +/- 64 mm.

The axis 2 assembly forms an independent single-axis diffractometer that can be slightly lifted up by the air pad. It is equipped with coarse and fine theta rotations. Motor resolution for the fine rotation is 0.00008 arcsec, which results in a smooth motion. In practice, steps of 0.1 arcsec are sufficient for rocking curve measurements.

Crystals mounted on axes 1 and 2 can be translated along and rotated about the reciprocal vector directions and tilted about horizontal axes normal to the translation directions.

Two Bicron scintillation detectors are used for monitoring intensities reflected from monochromator and sample crystals. They can be translated in the directions normal to the respective beams. Detector 2 has an entrance window that is 5” in diameter, which is sufficient to accept photons from about 4” diameter samples at a theta Bragg angle close to 45 degrees. To date, images of Bragg reflecting samples have been registered on photographic materials. A film cassette must be inserted manually.

Most movements of the instrument segments are motorized and automated under EPICS software control. Also, rocking curve measurements and searches for the optimal tilt angle for the sample are computer controlled.

The TTU is used predominantly for testing prototype monochromators and single crystals to be used at the APS. The tests consist of measuring rocking curves in double-crystal geometry and taking crystal images, i.e., taking topograms. The TTU was also used for testing an interferometer, multilayer structures, and crystals for a customer unrelated to the APS.

High heat load monochromator testing has been performed in a few stages. Typically, a monochromator is first tested “free-standing” and then mounted into a holder for use with synchrotron radiation. The mounted crystal is again tested on the TTU. Usually the first mount introduces strains, and mounting screws have to be readjusted. Testing is repeated (sometimes a few times) until strains are removed.

During the past year, the TTU has been used to test 48 optical elements for various CATs.

3.3.4 Beamline Controls and Data Acquisition

The Experimental Facilities Division has undertaken the development of standard beamline software (and related electronic hardware) to support scientific users of the APS, in collaboration with and on behalf of APS CAT developers. The objectives of this undertaking are to maximize the quality of the user software that APS developers as a group can produce; to set minimum standards for quality and ease of use, on which all APS users can depend; and to ease the migration of users and experiments from one APS beamline to another. The expectations are that we will address needs common to many APS users and CAT developers, and that CAT developers will concentrate on needs unique to their beamlines and users.

The degree to which the objectives are met depends in part on the willingness and ability of CAT developers to implement and extend XFD-developed software. Developers representing all APS CATs agreed early on to base their beamline software on EPICS, where feasible, and to collaborate in its development. This agreement served principally to authorize XFD's early commitment to developing EPICS-based beamline software. Most of the current CAT developers are implementing XFD software on their beamlines or are working toward this end.

In return, XFD provides many forms of technical support to ensure that CAT developers have access to the tools and information required to apply and extend our software effectively: videotaped classes on EPICS development; workshops on beamline software; loaner development systems (VME crate, processor, licenses, etc.); technical services, such as PROM programming, help with initial software installation, hardware and software troubleshooting, and system/ network-administration help; Web-based documentation of beamline software, electronic hardware, wiring standards, etc., for developers; online documentation of beamline software for users (see Fig. 3.4), and a documentation kit (in progress) with which CAT developers can extend our user documentation to include their own products; coordination of volume hardware specification and purchases by the CATs; procurement and distribution of VxWorks (the real-time operating system underneath EPICS) licenses; distribution of EPICS software and of EPICS-based beamline software; and telephone and e-mail support.

In addition to developing, collecting, documenting, maintaining, and distributing standard beamline software, XFD also implements beamline software for SRI-CAT and maintains SRI-CAT's file server, computer network, and workstations. This arrangement helps to ensure that the software we produce meets users' needs and is field tested before it gets distributed to other CATs. (It also means that XFD and SRI-CAT scientists normally perform experiments with software that is under active development.)

The beamline software developed by XFD is based on EPICS—a toolkit for building distributed control systems—which is the product of a large international collaboration of developers supporting accelerators (e.g., APS, CEBAF, DESY), synchrotron-radiation beamlines (principally at APS), telescopes (e.g., Gemini, Keck), and large detectors (e.g., the Gammasphere, and RHIC's Solenoidal Tracker). In addition to developing software useable by other members of the EPICS collaboration, XFD developed and maintains the software-distribution mechanism for the collaboration. In these ways, we help to "pay" for the technical support burden imposed by APS and CAT developers on other EPICS collaboration members and for new developments in EPICS of which APS users are the principal beneficiaries.

Because synchrotron-radiation users and developers are a minority in the EPICS collaboration and because some of our users' needs are atypical of the collaboration as a whole, it is essential that we find ways to influence the direction in which EPICS development proceeds. Recently, a technique that allows limited reprogramming of a live control system, for which we had been lobbying for several years, became a standard part of EPICS. (The technique was developed largely by APS ASD with some funding and much beta-testing support from XFD. Developers at Los Alamos also made substantial contributions.) Currently, we are working to keep two topics near the top of the collaboration's agenda: native support for large arrays, structured data, and data compression; and development of cross-platform tools.

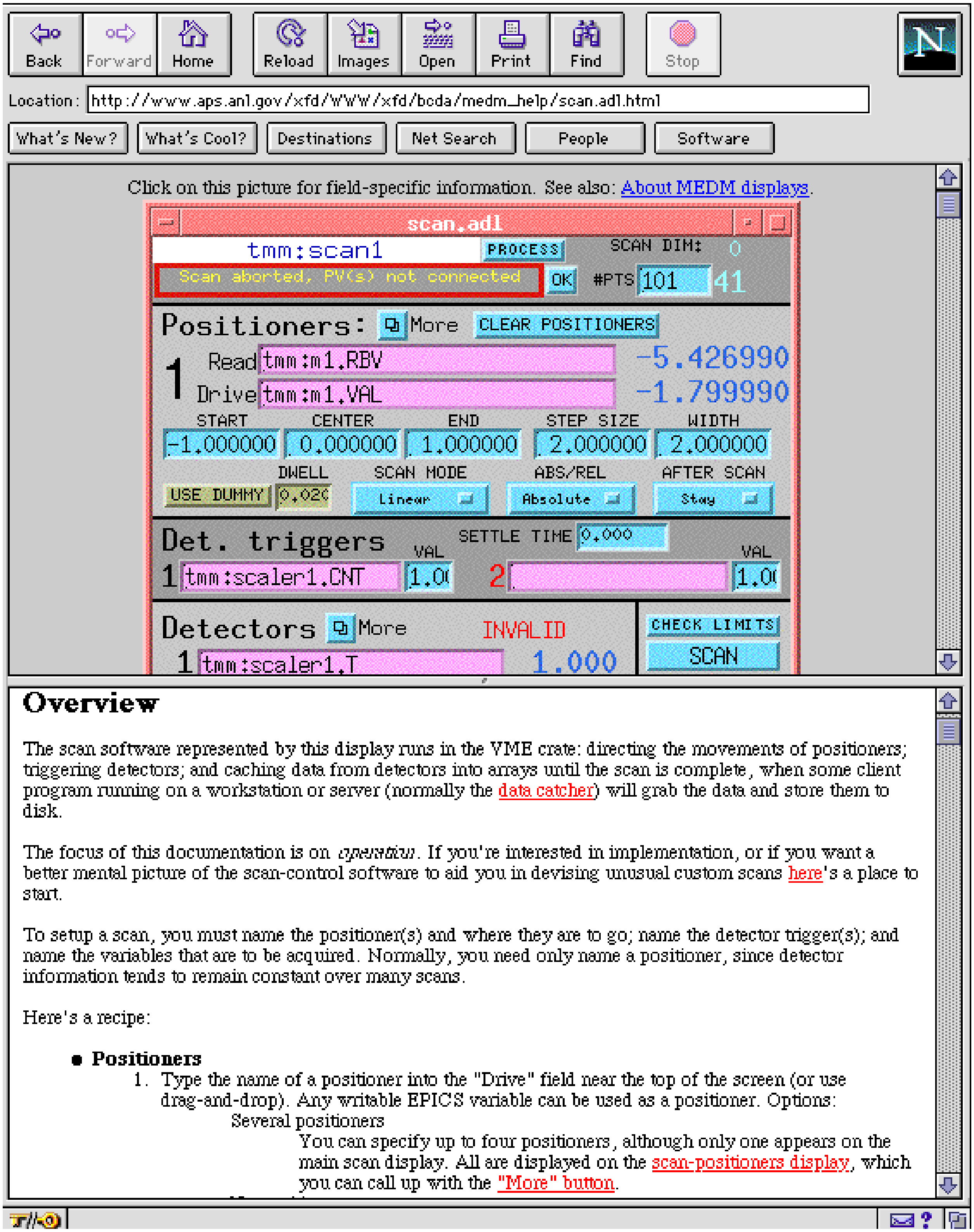


Fig. 3.4 On-line documentation of beamline control software for users

User’s View of Current Beamline Software

From a user’s viewpoint, EPICS-based beamline software looks like a collection of objects (motors, slits, optical tables, scalers, scans, etc.) any of which can be grabbed and tweaked, moved, etc., at any time. Associated with each object is a set of displays, with varying levels of detail, that run on the workstations. (A typical display is shown in the top section of Fig. 3.4.) These displays contain the object’s fields, the numbers and character strings that describe its state (e.g., a motor’s fields include its destination, current position, speed, name, engineering units, limits, backlash distance, etc.). Users think in terms of objects but actually manipulate fields; nobody cares about the distinction.

There are only three classes of objects/fields a user has to know about: positioners, detectors, and links. A positioner is any scalar quantity that can be written to, and most beamlines have tens of thousands of them, though the number of commonly manipulated positioners per beamline is more like a thousand. (Most “positioners” don’t actually move anything physical. The boundaries of a region of interest in a multichannel-analyzer spectrum and the gain of a current preamplifier are typical examples of scannable positioners.) In principle, all positioners can be scanned, and all can be the targets of run-time calculations (see “virtual machines” below). Commonly scanned positioners have private scan parameters attached to them, so they can be scanned by pressing a single button. There is a distinction between positioners that move and settle in less than around a millisecond and those that require many milliseconds or more to complete a motion, but the distinction is important only in setting up scans.

Similarly, a detector is any quantity that can be read. (Vector-valued detectors currently require special handling, because EPICS lacks native support for multidimensional arrays.) Again there is a distinction important only for scans between fast detectors such as ADCs and integrating detectors that require triggering and signal completion, such as scalers and multichannel analyzers. A scan is a vector-valued detector that requires triggering and signal completion—not fundamentally different from, say, a multichannel analyzer.

A link is the EPICS name of a positioner or a detector, coupled with an instruction that tells linked software what to do. More precisely, a link is a field into which the user can type the name of a positioner or detector, but users do not care about this distinction. Advanced users build virtual machines at run time using links. (Novices do this also, but they do not usually realize they are doing it.) In effect, links and displays containing them constitute a graphical programming language for users.

Beamline software is distributed among workstations and VME processors connected by a network. This allows an entire beamline to be controlled and monitored from any source (local or remote) without recabling. Most of the controlling software runs autonomously in the VME crates, while software tools running on the workstations merely provide a graphical user interface and collect cached data. VME crates periodically store their states to the file server and restore them during reboots. Usually, they can crash or be rebooted during an experiment with minimal or no consequences for the user (although scans cannot be continued through a reboot). Workstations can nearly always be rebooted without affecting the state of an experiment.

Control of VME-resident software is shared, so that several independent users (and software tools, such as the diffractometer-control program, SPEC) can operate overlapping sets of beamline equipment. This allows graphical and command-line user interfaces to be active simultaneously, both with full and independent access to beamline hardware. It also allows a remote user to collaborate effectively in an experiment. Currently, collisions between the various command streams that share control of a beamline are handled naively. Although EPICS has a good access-control system, we have not had time to apply it.

The VME-resident software can be modified, within limits, at run time. This allows users to build virtual machines that run autonomously in the crate. (Examples: the user can slave a voltage output to an arbitrary function of the beam current and beam position; the user can arrange to disable one motor whenever another motor is moving, is within a specified range of positions, has hit a software limit, etc.; the user can implement a theta/2-theta coordination and scan it as though it were a simple motor.) The latest version of EPICS also allows developers to change any motor assignment at run time (to work around failed hardware, for example). We have not yet addressed the user-interface details that will allow users to do this.

Actual accomplishments in software development and support are probably beside the point of this report, because software is not the end product here. However, by design, many of our activities are not obvious in the user's view of beamline software presented thus far (our real accomplishment), but reviewers should nevertheless know what we've been doing. Here is a list of last year's highlights:

- Responded to roughly 5000 requests for technical support, ranging from simple requests for vendor information to installation of EPICS and beamline software on a CAT's file server.

- Set up and outfitted network-support and beamline-control labs.

- Performed system and network administration for six beamlines and related labs.

- Installed and configured standard beamline software in 15 XFD labs and ten SRI-CAT experiment stations.

- Performed extensive trouble shooting of the Oregon Micro Systems VME58 step-motor controllers, and loaded new firmware into 20 boards.

- Designed and tested 190 motor-controller signal-transition boards (135 of these boards are now in service at APS).

- Made many improvements to the data catcher, the program that displays and stores scan data.

- Developed a data browser for hierarchical data format (HDF) files, and investigated HDF performance. (HDF is the standard selected by a collaboration including developers from APS and several neutron-scattering facilities to underly a common data-file format.)

- Developed Web pages for hardware technical support, distribution of

EPICS and beamline software, online documentation of beamline software, and an EPICS learning system for users and developers.

- Hosted beamline-controls workshop and collaboration meetings, EPICS users and developers classes, and an IDL class.

- Developed software support for the following devices:

  – HP laser interferometer

  – Moller-Wedel autocollimator

  – Laser Doppler angle encoder

  – Lakeshore temperature controller

  – Various single and double-crystal monochromators

  – Mirrors, slits, and filters

  – Various incremental-encoder interfaces

  – Keithley scanning multimeters

  – Multichannel-analyzer regions of interest

3.3.5 Leveraging of APS Funds

The IDs and FEs for the 20 APS user sectors that are currently under development represent a total investment by the APS of about $50 million. The CATs have leveraged this investment significantly by raising an additional $155 million to construct and instrument the beamlines outside the shield wall in these sectors. A breakdown of the CATs' funding sources is given in Fig. 3.5. The XFD staff has assisted many of the CATs in their fundraising efforts by working with them to develop designs and cost estimates and by providing information to their program managers during site visits.

3.3.6 User Procurements of Standard Components

The APS beamline standard components designs are available to the APS users through the Design Exchange, as described earlier. A library with over 180 components that have been designed, tested and installed is available to the users to procure either as they are or modified to meet the requirements of their beamline designs. All contracts to procure components for the APS beamlines were signed with an option clause that can be exercised to purchase up to 10 times the quantity procured within a year from the date the contract was signed. The following types of components are available in the DX library:

- Enclosures:

  – First Optics Enclosures

  – White Beam Experiment Stations

  – Monochromatic Experiment Stations

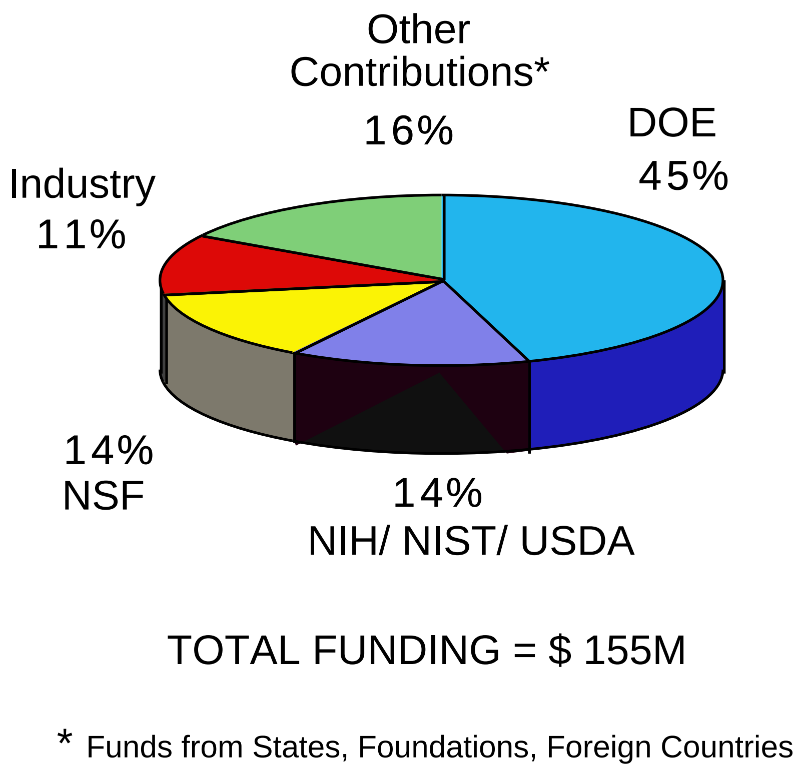


Fig. 3.5 Funding sources for APS Collaborative Access Teams

- Beamline Transports:
  - Shielded Pipes
  - Shielded Cabinets
  - Shielded Supports
- Collimators
- Tables (Support Structures)
- Windows
- Filters
- Slits
- Integral Shutters
- Beam Position Monitors
- Photon Masks

A process was initiated by XFD to support the user procurements and ensure that the delivered components meet the user's requirements. Once the user beamline design is reviewed by the XFD Beamline Review Committee, the procurement process starts.

Users who wish to exercise an option on the APS designs can view a comprehensive list of all the various types of components along with the option price and the time for its delivery from the vendor. The request is then submitted to the User Technical Interface Office, where it is forwarded to the XFD Project Engineer. A meeting is then held to review the user's requirements. Participants in the meeting include the cognizant engineer who designed the component, the installation coordinator, the purchasing agent, the User Technical Interface Group Leader, and the XFD Project Engineer. The responsibilities carried out by the participants are described in Fig. 3.6. Once the procurement process starts, biweekly status reports are issued to the user.

The users have gained the following benefits through this process.

- The components have been designed, and prototypes have been built and tested.

- Trained vendors have been established.

- Inspection procedures have been well established, guaranteeing quality product.

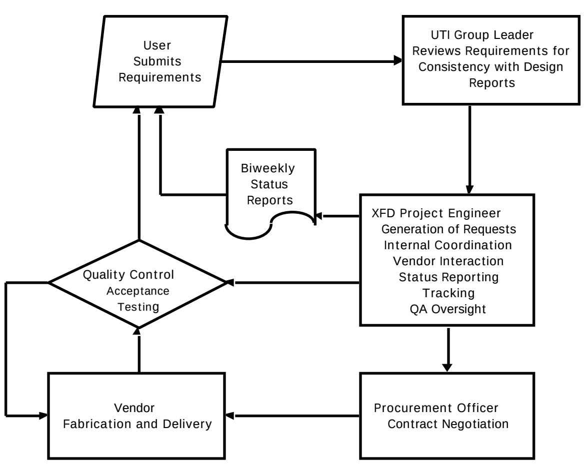


Fig. 3.6 User Procurement Flow Process

- The process assures the safe operation of the component and the beamline.

Through the use of the above-mentioned process, the cost savings to the users was over 12 million dollars. To date the users have ordered over 300 standard components through the APS for a total of 13 million dollars.

3.3.7 The Inter-CAT Technical Working Group

The Inter-CAT Technical Working Group (TWG) was established by the CATs in September 1994 to facilitate CAT-APS and CAT-CAT interactions and information exchange on technical issues, identify common CAT needs, and promote sharing of intellectual resources among the CATs. Each CAT has designated one or more TWG representatives, who meet on a monthly basis; generally, 20-30 CAT members attend each meeting, along with the XFD User Technical Interface Group Leader. Jim Viccaro (CARS-CAT) was the first TWG Chair; in January 1997, he was succeeded by the current co-Chairs, Dean Chapman (Center for Synchrotron Radiation Research and Instrumentation, Illinois Institute of Technology) and Dean Haeffner (SRI-CAT).

A regular feature of TWG meetings is the "APS facility update." Topics presented by XFD staff as part of these updates have included the following:

- Performance of high heat load optics

- Performance of data acquisition systems

- Liquid nitrogen distribution options
- Specifying and installing the Personnel Safety System on experiment stations
- X-ray optics metrology and fabrication capabilities available to users
- APS vacuum policy
- APS-supplied equipment and layouts for User Shops
- Using the APS Design Exchange

3.3.8 CAT Chats

In September 1995, XFD initiated a series of weekly "CAT Chats," informal Friday afternoon meetings that give CAT members an opportunity to present questions and issues directly to XFD management. The issues discussed at CAT Chats have covered a wide range of technical, administrative, safety, and user service topics. If a question cannot be answered on the spot, XFD provides an answer at the following meeting. In addition, at the beginning of each meeting the XFD Associate Division Director for Operations gives an update on the operations schedule, shielding validation activities, etc., for the coming week. The updates, questions, and answers are compiled into weekly minutes, which are distributed at the subsequent meeting and posted on the Web. To date, 65 CAT Chats have been held.

3.4 References

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